Evidence for atmospheric pollution across the Permian-Triassic transition

Hochuli, Peter A ; Schneebeli-Hermann, Elke ; Mangerud, Gunn ; Bucher, Hugo

Abstract: Evidence for a cause-and-effect relationship between the emplacement of the Siberian Traps large igneous province and the Permian-Triassic marine mass extinction has been growing over the past decades. However, how the Siberian Traps volcanism affected the terrestrial vegetation is still a matter of controversy. Here, we demonstrate that a substantial part of plants' life cycle, namely their reproductive organs, was adversely affected by environmental conditions. Effects include malformed spores and pollen grains, unseparated tetrads, and darkened walls of spores and pollen (sporoderm) from Permian-Triassic sediments from the Finnmark Platform offshore Norway. The co-occurrence of these morphological changes with the main carbon isotope excursion and the marine mass extinction may suggest that they were caused by atmospheric pollution linked to Siberian Traps emissions.

DOI: https://doi.org/10.1130/G39496.1

Evidence for atmospheric pollution across the Permian–Triassic transition

Peter A. Hochuli[1], Elke Schneebeli-Hermann[1], Gunn Mangerud[2], Hugo Bucher[1]

[1]*Institute and Museum of Palaeontology, University of Zurich, Karl Schmid-Str. 4, CH-8006 Zurich, Switzerland*

[2]*Department of Earth Science, University of Bergen, Postboks 7803, N-5020 Bergen, Norway*

DATA REPOSITORY

Plate 1
Deformed Spores
*England Finder coordinates; scale bar 20 μm

1 *Uvaesporites imperialis* (normal); 7128/12-U-1 - 112.76m; J53/1*

2, 6 *Uvaesporites imperialis* (normal and deformed); 7128/12-U-1 - 112.76m; J51*

3 *Uvaesporites* sp. (folded surface); 7128/12-U-1 - 115.9m; J53/1*

4, 5 *Uvaesporites imperialis* (deformed trilete mark and shape); 7128/12-U-1 114.37m; G34/4*

7 *Uvaesporites imperialis* (**reduced inner body**); 7129/10-U-1 - 63.48m; S40/1*

8,9 *Uvaesporites imperialis* (deformed trilete mark); 7128/12-U-1 - 108.79m; E50/3*

10 *Densoisporites* sp. (partly brocken, deformed trilete mark); 7128/12-U-1 - 112.76m; L60/2*

11 Trilete spore (?*Uvaesporites* sp., deformed trilete mark); 7128/12-U-1 114.37m; G43/4*

12 Spore tetrad and trilete spore with deformed trilete mark; 7128/12-U-1 - 94.88m; L30/2*

13 Trilete spore (?*Uvaesporites* sp., deformed trilete mark); 7128/12-U-1 - 94.88m; E37/2*

Plate 1

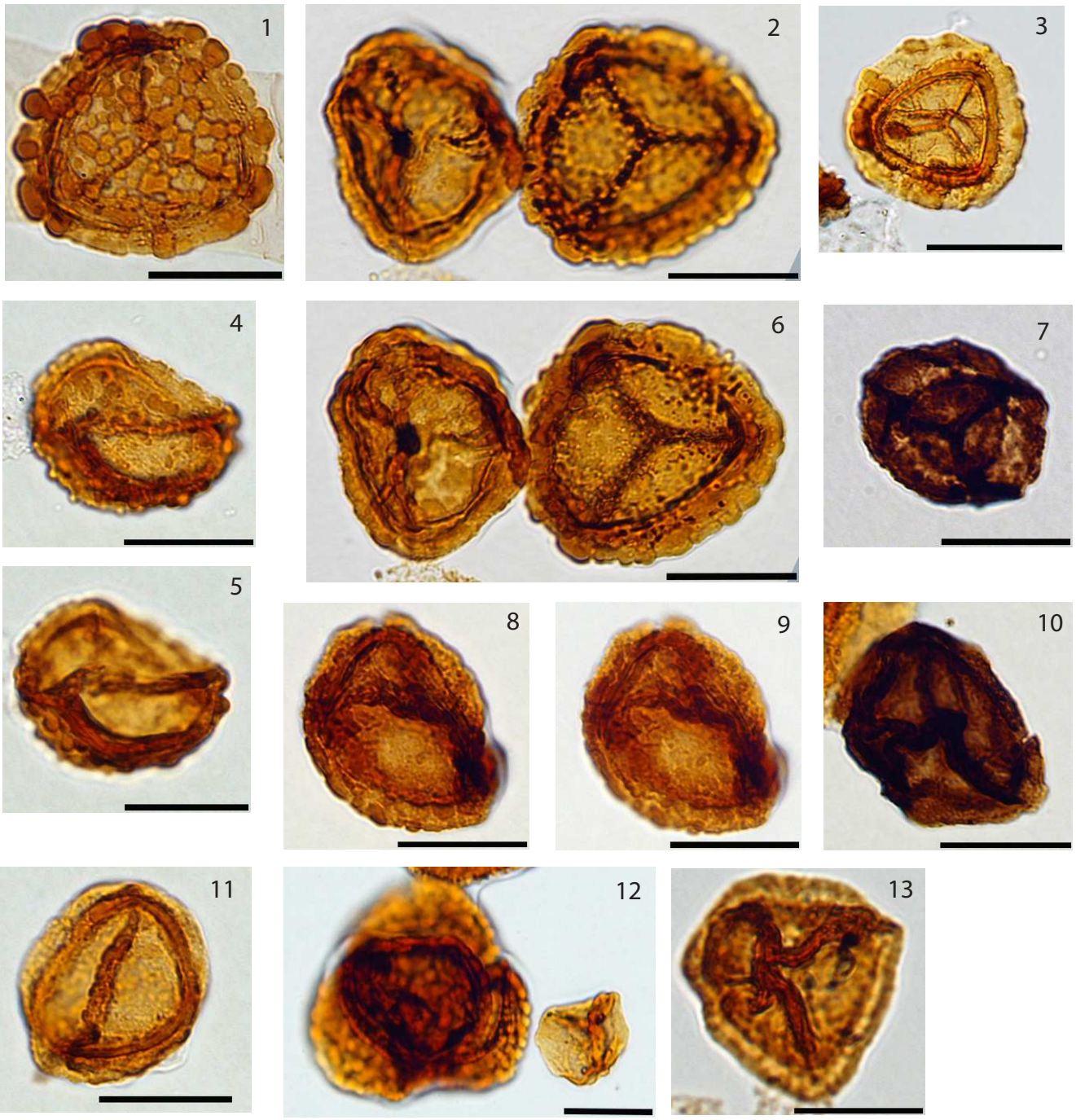


Plate 2

Tetrads
*England Finder coordinates; scale bar 20 μm

1 *Uvaesporites* sp. (tetrad); 7128/12-U-1 - 115.9m; H41/1*

2,3 *Densoisporites* sp. (tetrad); 7128/12-U-1 - 108.79m; E61*

4 *Densoisporites* sp. (welded tetrad); 7128/12-U-1 - 105.69m; P61/3*

5 Trilete spores (tetrad with unequal spore size); 7129/10-U-1 - 63.48m; Q52/3*

6 *Ephedripites* spp. (polyade); 7128/12-U-1 - 81.87m; G70/2*

7 Tetrad with one aborted spore; 7129/10-U-1 - 63.48m; Q41/3*

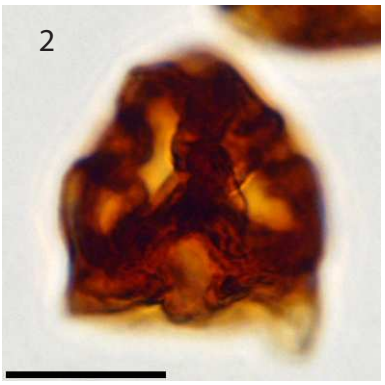
8 Trilete spores (double tetrad); 7128/12-U-1 - 94.88m; E54/4*

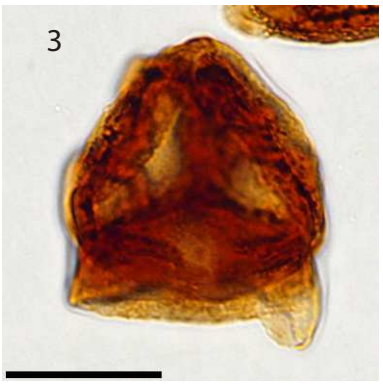
9 *Ephedripites* spp. (tetrad); 7128/12-U-1 - 94.88m; E36*

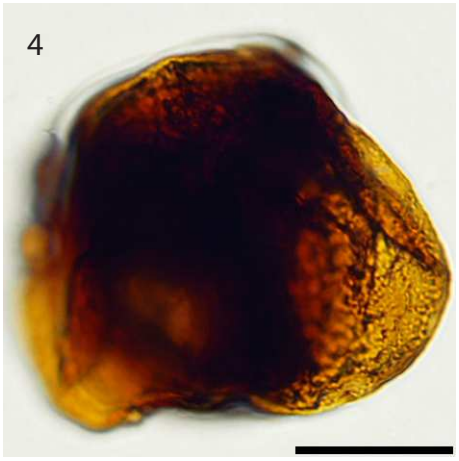
10 deformed tetrad (welded tetrad); 7128/12-U-1 - 105.69m; P33*

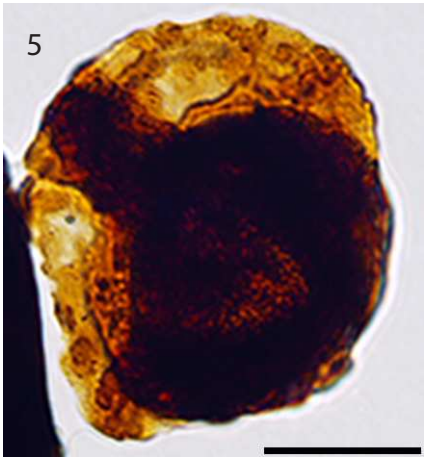
11 Bisaccate pollen grains (tetrad); 7128/12-U-1 - 84.74m; Q36/3*

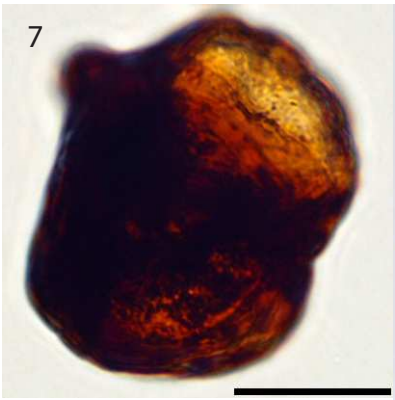
Plate 2

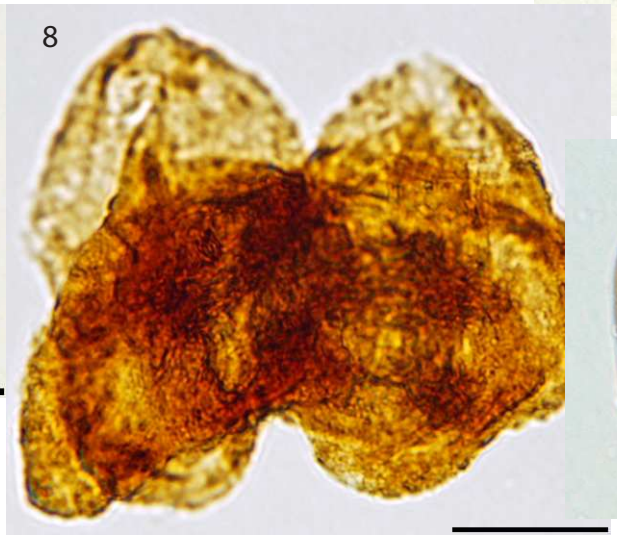












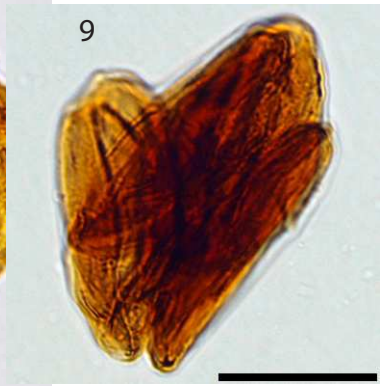


Plate 3
Deformed bisaccate pollen grains
*England Finder coordinates; scale bar 20 μm

1 Bisaccate pollen grain *(?Klausipollenites sp.* with reduced and deformed saccus); 7128/12-U-1 - 116.47m; O57/3*

2 Taeniate bisaccate pollen grain (deformed taeniae and sacci of unequal size) 7128/12-U-1 - 119.09m; M54/4*

3 Taeniate bisaccate pollen grain (deformed – oblique taeniae); 7128/12-U-1 - 112.76m; L36/2*

4 Taeniate bisaccate pollen grain (deformed central body and sacci); 7128/12-U-1 - 119.09; 19.7/127.2*

5 Bisaccate pollen grain (folded and deformed central body); 7128/12-U-1 - 112.76m; Q57/1*

6 Bisaccate pollen grain (one abnormal saccus); 7129/10-U-1 - 65.68m; U52/2*

7 Taeniate bisaccate pollen grain (deformed taeniae and sacci of unequal size); 7128/12-U-1 - 112.76m; L36/1*

8 Bisaccate pollen grain (?*Klausipollenites* sp., deformed and modified number of sacci 7128/12-U-1 - 87.70m; N26/1*

9 Taeniate bisaccate pollen grain (?*Striatoabieites* sp., (reduced taeniate and unequal size of sacci); 7128/12-U-1 - 119.09m; Q53/2*

10 Bisaccate pollen grain (deformed central body and sacci) 7129/10-U-1 - 65.68m; M47/4*

11 Taeniate bisaccate pollen grain (deformed taeniate and sacci) 7128/12-U-1 - 119.09m; L56/2*

12 Klausipollenites sp. (three grains with deformed sacci); 7128/12-U-1 - 105.69m; G31*

12 Bisaccate pollen grain (deformed sacci of unequal size); 7129/10-U-1 - 65.68m; M27/4*

14 *Potonieisporites* sp. (asymmetric saccus); 7128/12-U-1 - 141.09m; H28*

Plate 3

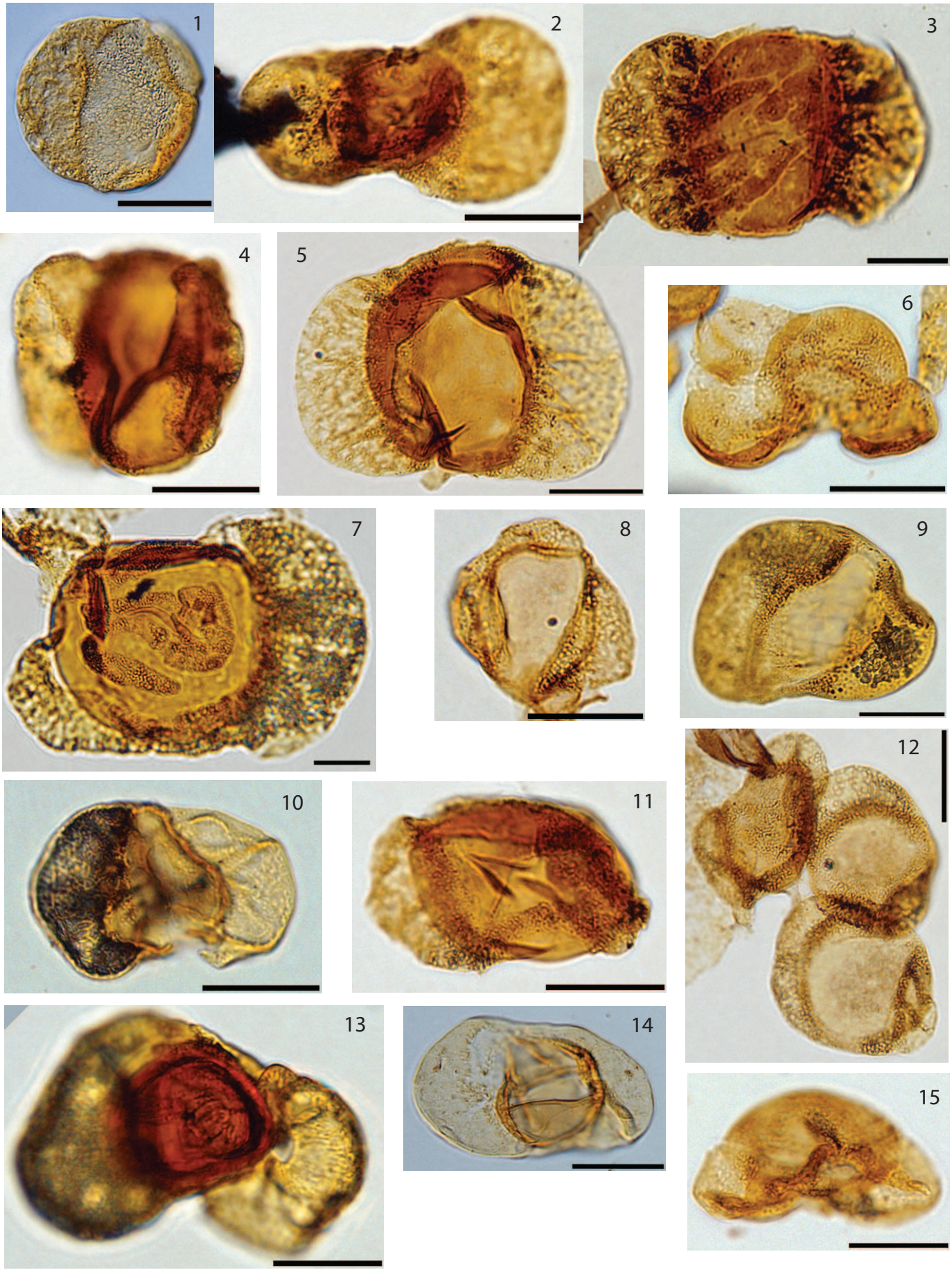


Plate 4
Darkened sporomorphs
*England Finder coordinates; scale bar 20 μm

1 Bisaccate pollen grains (dark + translucent); 7128/12-U-1 - 81.87m; E46/1*

2 *Uvaesporites imperialis* (dark + translucent); 7128/12-U-1 - 114.37m; G39/4*

3 4 Trilete spores - (dark + translucent); 7128/12-U-1 - 108.79m; S38/1*

4 2 tetrads (dark + translucent); 7129/10-U-1 - 63.48m; Q45/4*

5 *Uvaesporites* spp. (dark + translucent); 7129/10-U-1 - 63.48m; V61/1*

6 Tetrad (dark, "mazerated"); 7129/10-U-1 - 63.48m; F60/4*

7 *Endosporites papillosus* (translucent) and trilete spore (cf. *Uvaesporites* sp., dark) 7128/12-U-1 - 105.69m; M66/3*

8 *Endosporites papillosus* (dark); 7129/10-U-1 - 63.48m; J30/2*

9 *Densoisporites* sp. (deformed and darkened); 7128/12-U-1 - 105.69m; G34*

10 *Uvaesporites* sp. (dark); 7128/12-U-1 - 105.69m; E44/3*

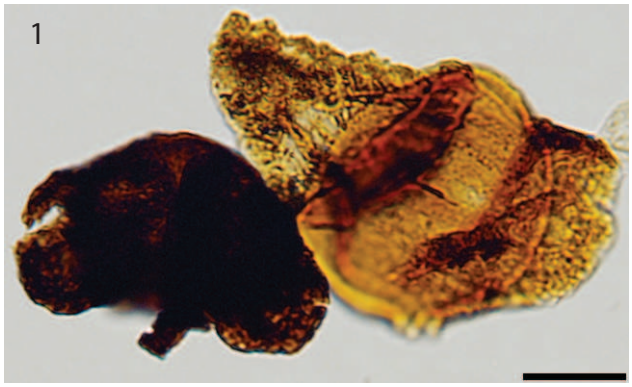
11 Taeniate bisaccate (dark); 7128/12-U-1 - 81.87m; E29/1*

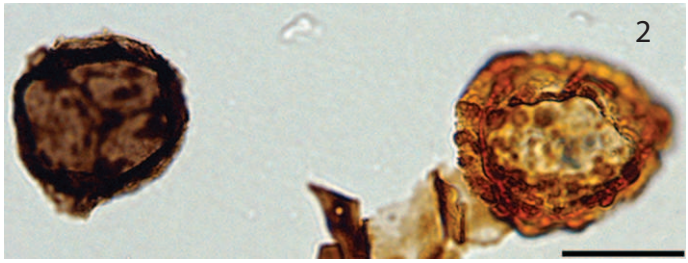
12 Tetrad (dark); 7129/10-U-1 - 63.48m; R52/2*

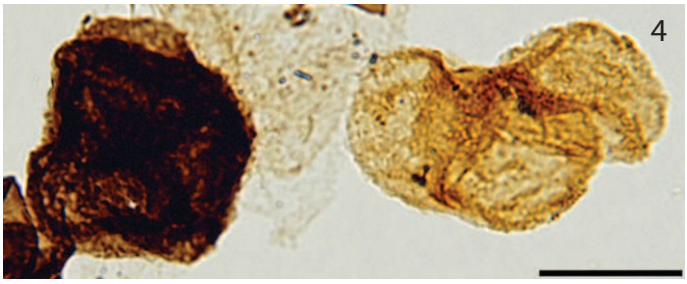
13 Fungal remains (dark) + acritarchs (translucent); 7129/10-U-1 - 63.48m; Q46/4*

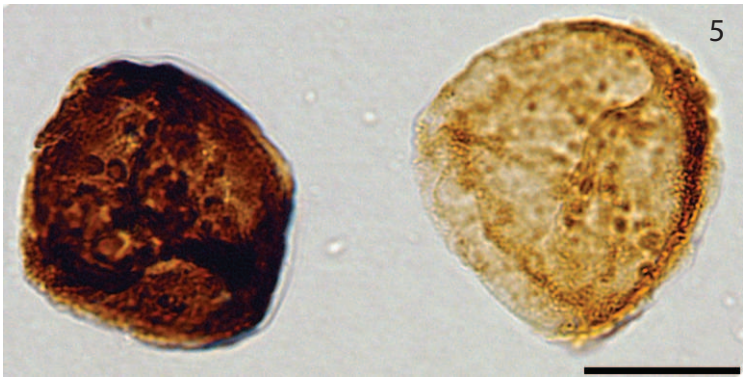
14 *Lueckisporites* sp. (dark); 7129/10-U-1 - 63.48m; R51/4*

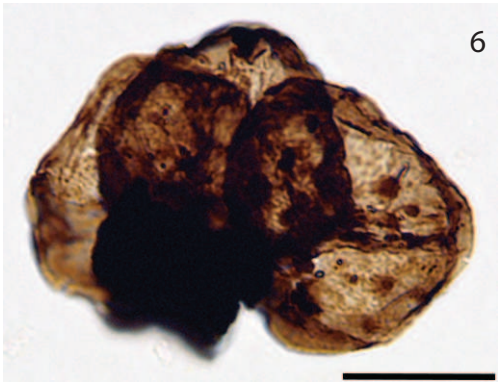
Plate 4

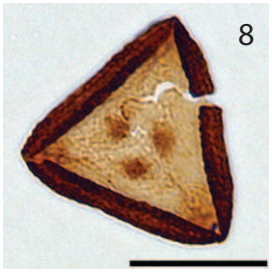


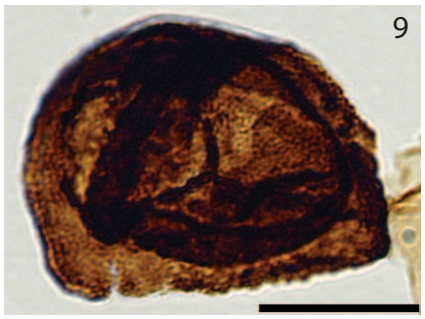


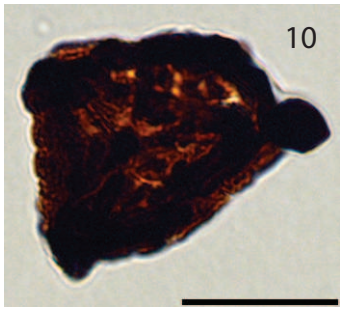


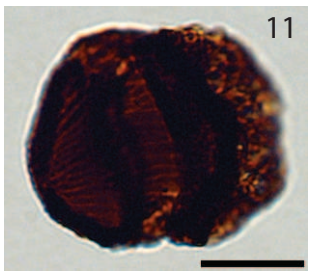


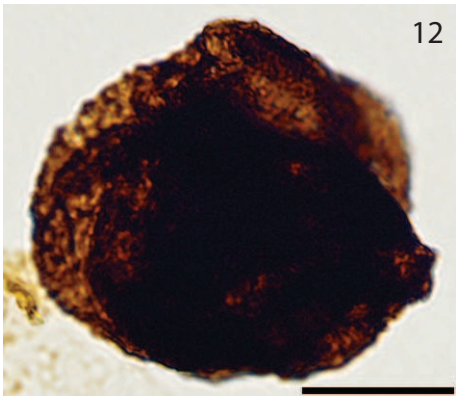












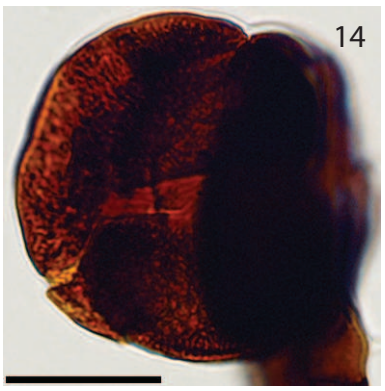


Table DR1

Raw counts

	Undeformed sporomorphs	Indeterminate sporomorphs*	tetrads	deformed tetrads	Deformed sporomorphs	Darkened sporomorphs	Sum
65.64	59	148	2	5	54	14	282
67.86	20	100	3	3	48	18	192
69.3	41	167	1	1	49	11	270
73.39	40	170	2	2	35	21	270
79.85	50	155	2	3	42	23	275
81.87	40	148	1	7	51	26	273
84.74	56	137	1	3	43	23	263
85.95	26	193	1	2	46	36	304
87.7	100	103	6	4	52	6	271
90.96	67	152	0	0	50	4	273
94.88	73	120	5	11	68	5	282
100.04	69	114	9	7	58	4	261
105.69	54	124	7	7	62	14	268
108.79	63	113	1	8	66	21	272
110.06	40	129	10	13	48	24	264
112.76	71	116	5	8	62	20	282
114.37	63	130	4	9	31	33	270
115.29	17	168	6	21	48	28	288
115.9	44	113	10	14	69	17	267
116	22	125	3	16	71	10	247
116.46	22	150	1	4	85	13	275
116.47	29	129	0	2	109	3	272
117.49	19	165	1	0	90	0	275
119.09	35	133	0	0	130	0	298
141.09	46	164	0	0	17	0	227

- * due to corrosion or insituable orientation

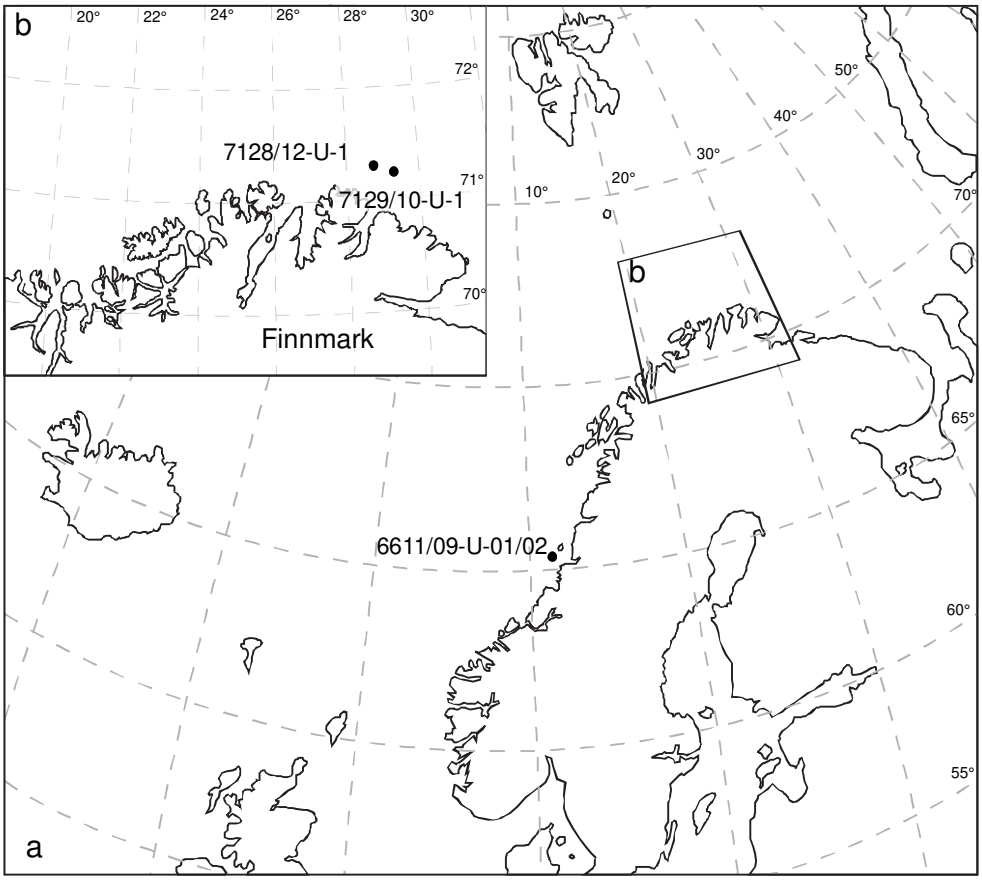


Figure DR1 : Location of core sites in Norway.

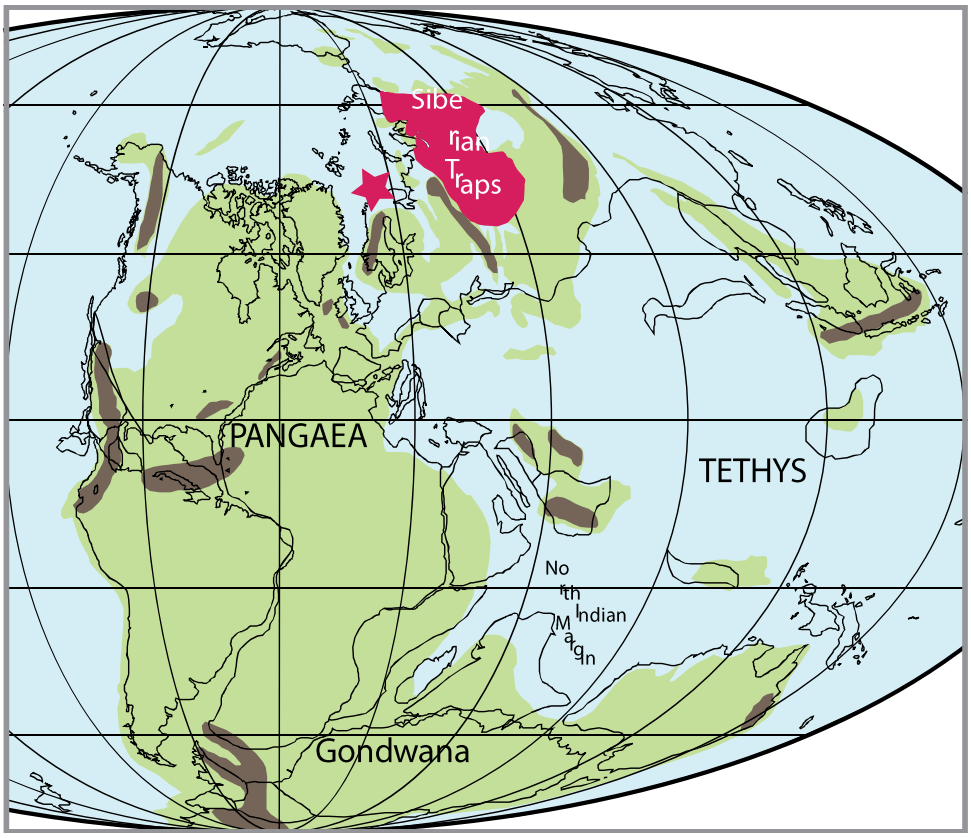


Figure DR2 : Permian–Triassic palaeogeography after Smith et al., 1994 and Golonka and Ford, 2000. Palaogeographic position of the Finnmark cores is indicated by a star. Palaegeographic position and extent of the Siberian Traps after Reichow et al., 2009

Reference :

Golonka, J. and Ford, D. 2000. Pangaean (Late Carboniferous–Middle Jurassic) paleoenvironment and lithofacies. Palaeogeography, Palaeoclimatoloy, Palaeoecology, 161, 1–34.

Reichow, M.K., Pringle, M.S., Al'Mukhamedov. A.I., Allen, M.B., Andreichev, V.L., Buslow, M.M., Davies, C.E., Fedoseev, G.S., Fitton, J.G., Inger, S., Medvedev, A.Ya., Mitchell, C., Puchkov, V.N., Safonova, I. Yu., Scott, R.A., Saunders, A.D. 2009. The timing and extent of the eruption of the Siberian traps large igneous province: implications for the end-Permian environmental crisis. Earth and Planetary Science Letters, 277, 9–20.

Smith, A.G., Smith, D.G., and Funnell, B.M., 1994, Atlas of Mesozoic and Cenozoic Coastlines: Cambridge, UK, Cambridge University Press, 109 p.